
**E-ISSN:** 2618-0618
**P-ISSN:** 2618-060X

www.agronomyjournals.com
2024; 7(9): 260-264
Received: 21-06-2024
Accepted: 30-07-2024

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# Synergistic effects of inorganic and organic fertilizers with *Kappaphycus alvarezii* bio-stimulant on yield attributes of wheat (*Triticum aestivum* L.)

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**DOI:** https://doi.org/10.33545/2618060X.2024.v7.i9d.1516

**Abstract**
This study investigates the synergistic effects of inorganic and organic fertilizers, augmented with a bio-stimulant derived from *Kappaphycus alvarezii*, on key yield attributes of wheat (*Triticum aestivum* L.). Grain yield, straw yield, biological yield, and harvest index were evaluated to assess the productivity and efficiency of wheat cultivation under various treatment combinations. Significant interactions among the three factors *i.e.*, inorganic (NPK), organic fertilizer (FYM), and bio-stimulant (Seaweed-based) were observed in grain yield, with the highest yield of 70.40 q $ha^{-1}$ recorded in $T_{18}$ (RDF @100% + FYM@16.5 t $ha^{-1}$ + SWBS@1250 ml $ha^{-1}$) in pooled basis. Straw yield also showed significant responses, with $T_{18}$ exhibiting the highest yield of 105.60 q $ha^{-1}$ in pooled basis. In terms of biological yield, $T_{18}$ yielded the highest at 176.00 q $ha^{-1}$ in pooled basis, indicating substantial biomass production. Furthermore, the harvest index, representing the efficiency of grain production, was notably high in $T_{18}$ at 40.00% in pooled basis. These findings underscore the potential of integrated fertilizer and bio-stimulant applications in enhancing wheat productivity and resource use efficiency.

**Keywords:** Wheat, yield, NPK, FYM, Kappaphycus alvarezii, seaweed, bio-stimulant, etc

## Introduction
Agricultural productivity faces a critical challenge in meeting the escalating global demand for food. With the burgeoning world population, ensuring food security necessitates the optimization of crop yield while minimizing environmental impact. Wheat (*Triticum aestivum* L.), being one of the primary staple crops worldwide, holds significant importance in addressing this challenge. Enhancing wheat yield through sustainable agricultural practices is imperative to meet the dietary needs of an ever-expanding population. In this context, the integration of fertilizers and bio-stimulants has emerged as a promising strategy to boost crop productivity while maintaining soil health and ecological balance. Both inorganic and organic fertilizers play pivotal roles in providing essential nutrients to crops, thereby influencing various yield attributes. Moreover, bio-stimulants derived from natural sources offer a sustainable approach to enhance plant growth, development, and resilience to environmental stresses.
The term Bio-stimulants refers to materials other than fertilizers, that promote plant growth (Kauffman *et al.*, 2007) [2]. Seaweed based bio-stimulants are defined as stimulating products the function of which is to stimulate plant nutrition processes. *Kappaphycus alvarezii*, a red seaweed species rich in bioactive compounds, has gained attention as a potent bio-stimulant in agricultural practices. Its unique biochemical composition, including polysaccharides, amino acids, vitamins, and phytohormones, offers multifaceted benefits in promoting plant growth and productivity (Vera *et al.*, 2011) [6]. By harnessing the synergistic effects of inorganic and organic fertilizers with *Kappaphycus alvarezii* bio-stimulant, this study aims to explore novel avenues for maximizing wheat yield while minimizing the ecological footprint of agricultural activities.

## Materials and Methods
The primary objective of this research was to explore the potential synergistic effects of

inorganic and organic fertilizers complemented with a bio-stimulant derived from *Kappaphycus alvarezii* on the yield characteristics of wheat (*Triticum aestivum* L.). This section offers a concise overview encompassing critical aspects of the study, such as the temporal and geographic parameters, soil composition, climatic conditions of the experimental site, the selection of crops or planting materials, various treatments administered, experimental layout and design, data collection methods, and statistical method employed. Presented herewith is a detailed outlining the specific methodologies and trials conducted in the investigation:

**Area of investigation**

The study was conducted for the two consecutive years starting with the rabi seasons 2021–22 and 2022–23 at Research Farm, Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj District of Uttar Pradesh. The experimental site of the research farm is in the geographic coordinates of Prayagraj District, at 26°55' N latitude and 81°76' E longitude. This area, which is 98 meters above mean sea level, is positioned 5 kilometers to the right of the Yamuna River's bank. It is part of the Upper Gangetic Plain Region, a wider Agro-Climatic Zone that includes the North Alluvial Plain zone (slope varying from 0 to 1%). It defines the Agro-Ecological Sub Region.

**Climatic conditions**

North-central Indian cities, including Prayagraj, are characterized by a humid subtropical climate. Three seasons occur in Prayagraj: warm, humid monsoon, mild, dry winter, and hot, dry summer. A high temperature of 40 °C (104 °F) to 45 °C (113 °F) is experienced during the summer months of April through June. From early July to September, the monsoon season occurs. December through February is the winter season. This region experiences what is known as the summer monsoon, or South-West monsoon, which is defined as the period of rainfall that begins in the middle of July and ends at the end of September. Most of the rainfall (75%) is brought about by the South-West monsoon, with an average of 900-1100 mm each year.

**Soil characteristics**

The experimental field's properties from a physio-chemical perspective are presented in Table 1.

**Experimental details**

The current research study employed a factorial randomized block design (*f*-RBD) with eighteen treatment combinations, replicated three times. These combinations were randomly assigned within each replication, resulting in a total of fifty-four plots across the research site. The wheat variety 5-SR05 was cultivated during the experimental years 2022-23 and 2023-24. This investigation incorporated a comprehensive nutrient approach, involving inorganic fertilizers such as NPK, farmyard manure, and bio-stimulant inputs from *Kappaphycus alvarezii*, an elkhorn sea moss species of red algae. Detailed field treatment information can be found in Table 2.

**Data collection**

Wheat grain samples were collected separately according to the treatments in the year of 2023 and 2024 *i.e.*, two consecutive years of research trails.

**Grain yield**

Following the harvesting of the wheat crop from the designated plot, the produce underwent manual threshing, achieved by beating the grains against a solid surface. Subsequently, the threshed grains were winnowed and cleaned individually. The resulting grain yield from each plot was documented in kilograms per plot (kg plot$^{-1}$) and subsequently converted into quintals per hectare (q ha$^{-1}$). It was ensured that the moisture content of the wheat was maintained at 12 percent throughout the process.

**Straw yield**

Prior to commencing the threshing operation, the weight of each plot's bundle, encompassing both straw and grain, was documented. Subsequently, the weight of the straw (in kilograms) was recorded by deducting the weight of the grain (in kilograms) from the overall bundle weight (in kilograms). This resultant value was then conveyed in terms of quintals per hectare (q ha$^{-1}$).

**Biological yield**

To ascertain the biological yield of the wheat crop, measurements of both straw and grain yield were taken in each net plot two days after harvest. Subsequently, these measurements were converted into quintals per hectare.

**Harvest index**

Harvest Index of wheat was computed from their respective grain yield and total (grain+ straw) yield by using following equation:

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,
Economic yield =grain yield
Biological yield = grain yield + straw yield

**Statistical analysis**

The study utilized a factorial randomized block design to investigate the effects of inorganic (NPK), organic fertilizer (FYM) and bio-stimulant (Seaweed-based) at different levels. This design was chosen for its ability to efficiently assess the impact of multiple factors while controlling for potential sources of variation. Factorial experiments delve into how multiple factors or input parameters influence the outcome of a process. Each trial in a factorial experiment encompasses all potential combinations of these factor levels, as outlined by Fisher in 1960 [1].

**Results and Discussion**

**a) Grain yield (q ha$^{-1}$)**

Grain yield is a pivotal metric in assessing the productivity and profitability of wheat cultivation. In the current study, it was found that all three factors *i.e.*, inorganic (NPK), organic fertilizer (FYM) and bio-stimulant (Seaweed-based) with different levels showed significant interaction in case of grain yield. In 2018, Yan *et al.* [7], also stated that there is a significant synergistic effect of bio-stimulant, NPK and FYM on overall yield, including grain, straw, and biological yield. At 0.05 level significant interaction between all three factors was observed in $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) followed by $T_{16}$ (RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS @1250 ml ha$^{-1}$) *i.e.*, 69.79 and 67.78 q ha$^{-1}$ respectively in first

year of research trail *i.e.,* 2022-23. In next year, a slight variation was recorded in grain yield which is more as compare to last year yield recorded. Interactions of FYM with bio-stimulant and NPK were found to be non-significant. Whereas NPK alone showed significance at 0.01 level. At pooled basis $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) was found to be best and showed highest yield about 70.40 q ha$^{-1}$ among all treatment combinations. In the study it was found that in most of the treatments where SWBS is applied @ 1250 ml ha$^{-1}$ have showed the good yield as compare to that one in which it is applied @ 625 ml ha$^{-1}$. In 2019, Pichereaux [4] and his co-workers also reported that the application of bio-stimulants resulted in observable changes in the wheat plants. One of the observed effects was a statistically significant increase in grain biomass. This is because, SWBS helps in stimulating the nutrient uptake and enhance stress tolerating power that helps in overall plant biomass development.

**b) Straw yield (q ha$^{-1}$)**

Wheat straw is a byproduct of wheat cultivation which is the dried stalks and leaves left over after wheat grains have been harvested. In this context, current study has showed significant results over different factors interaction on straw yield. In case of straw production, $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) has showed significant yield at 0.05 level *i.e.,* 104.78 q ha$^{-1}$ in first trail of research whereas in second trail it has showed yield about 106.42 q ha$^{-1}$ which is highest among all other treatments. The second-best output in straw yield was recorded in $T_{16}$ (RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) *i.e.,* 102.77 and 104.41 q ha$^{-1}$ in year 2022-23 and 2023-24 respectively. Whereas NPK has showed significant results at 0.01 level alone as well as with bio-stimulant interaction. The rest interactions were found to be non-significant in case of straw yield. All significant results were showed by plots applied with FYM @ 16.5 t ha$^{-1}$, this is because FYM can improve soil condition leading to enhanced plant growth and nutrient uptake. Phullan and colleagues (2017) [3] also reported that application of farmyard manure led to a significant improvement in shoot dry weight. On pooled basis $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) and $T_{16}$ (RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) were found to be best and second best among all treatments which have showed significant yield at 0.05 level *i.e.,* 105.60 and 103.59 q ha$^{-1}$ respectively.

**c) Biological yield (q ha$^{-1}$)**

The biological yield of wheat crop refers to the total amount of biomass produced by the wheat plant during its growth cycle. This includes all above ground plant parts such as leaves, stems, and grains which serves as a crucial indicator of the crop's overall productivity and potential yield. The current study in this context have showed some significant interactions between different factors. The interaction between all three factors *i.e.,* inorganic (NPK), organic fertilizer (FYM) and bio-stimulant (Seaweed-based) was recorded significant at 0.05 level. Interaction between inorganic (NPK) and bio-stimulant (Seaweed-based) was found to be significant at 0.01 level. In pooled basis only all three factors interaction together was recorded as significant at 0.05 level. The highest biological yield was found in $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) *i.e.,* 174.57 and 177.42 q ha$^{-1}$ followed by $T_{16}$ (RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) *i.e.,* 170.55 and 173.39 q ha$^{-1}$ in the year 2022-23 and 2023-24 respectively. At pooled basis biological yield was recorded as 176 q ha$^{-1}$ which was found to be highest in $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) among all treatments followed by $T_{16}$ (RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) *i.e.,* 171.97 q ha$^{-1}$. Here, all significant results were found in which SWBS was applied @ 1250 ml ha$^{-1}$, in fact in most of the treatments where it is applied at same dose have showed good biological yields. Similarly, Shukla *et al.,* in 2023 [5] also stated that foliar application of bio-stimulant derived from Kappaphycus alvarezii has demonstrated improved overall plant growth.

**d) Harvest index (%)**

The harvest index of a wheat crop is a vital metric that quantifies the efficiency of grain production relative to total biomass. It reflects the proportion of the plant's total biomass that is allocated to edible grain, offering insights into the crop's ability to convert resources into harvestable yield. In context to this, the current study has recorded that all three factors have showed significant results on harvest index. The maximum value of harvest index was recorded by $T_{18}$ (RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) *i.e.,* 39.98 and 40.02 followed by $T_{16}$ (RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$) *i.e.,* 39.74 and 39.78 in two consecutive years of research trails *i.e.,* during 2022-23 and 2023-24 respectively. Both inorganic-organic fertilizer and inorganic-organic-bio-stimulant interaction were found to be significant at 0.05 level. Whereas inorganic-bio-stimulant interaction was recorded significant at 0.01 level. Only slight variation was recorded in harvest index of wheat crop between two consecutive years of research trails. At first year (2022-23) of trail NPK and FYM alone found to be non-significant. At pooled basis only NPK-FYM -bio-stimulant interactions and bio-stimulant alone were recorded as significant at 0.05 level.

**Table 1:** Initial assessment of the soil samples in the experimental field for the years 2022 and 2023.

| Soil characteristics | Soil depth (0-15 cm) | |
|---|---|---|
| | 2022 | 2023 |
| Soil pH (1: 2.5) | 6.73 | 6.75 |
| Electrical conductivity (dS m$^{-1}$) | 0.16 | 0.17 |
| Bulk density (Mg m$^{-3}$) | 1.25 | 1.26 |
| Particle density (Mg m$^{-3}$) | 2.61 | 2.61 |
| Porosity (%) | 49.0 | 52.0 |
| Water holding capacity (%) | 50.11 | 47.73 |
| Organic carbon (%) | 0.302 | 0.305 |
| Available nitrogen (kg ha$^{-1}$) | 210.12 | 229.11 |
| Available phosphorus (kg ha$^{-1}$) | 14.75 | 18.10 |
| Available potassium (kg ha$^{-1}$) | 171.02 | 185.07 |

**Table 2:** Treatment combinations for wheat

| Notation | Treatment Combinations |
|---|---|
| $T_1$ | RDF @50% +FYM@12.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_2$ | RDF @50% + FYM@12.5 t ha$^{-1}$ + SWBS @1250 ml ha$^{-1}$ |
| $T_3$ | RDF @75% +FYM@12.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_4$ | RDF @75%+FYM@12.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_5$ | RDF @100% + FYM@12.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_6$ | RDF @100% + FYM@12.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_7$ | RDF @50% + FYM@14.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_8$ | RDF @50% + FYM@14.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_9$ | RDF @75% + FYM@14.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_{10}$ | RDF @75% + FYM@14.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_{11}$ | RDF @100% + FYM@14.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_{12}$ | RDF @100% + FYM@14.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_{13}$ | RDF @50% + FYM@16.5 t ha$^{-1}$ + SWBS@625 ml ha$^{-1}$ |
| $T_{14}$ | RDF @50% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_{15}$ | RDF @75% + FYM@16.5 t ha$^{-1}$ +SWBS@625 ml ha$^{-1}$ |
| $T_{16}$ | RDF @75% +FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |
| $T_{17}$ | RDF @100% + FYM@16.5 t ha$^{-1}$ +SWBS@625 ml ha$^{-1}$ |
| $T_{18}$ | RDF @100% + FYM@16.5 t ha$^{-1}$ + SWBS@1250 ml ha$^{-1}$ |

**Note:** RDF= Recommended Dose of Fertilizer, FYM = Farm Yard Manure and SWBS= Seaweed- based bio-stimulant

**Table 3:** Effect of combined use of inorganic fertilizer, organic manure, and foliar application of seaweed- based bio-stimulant on grain yield (measured in quintal per hectare) of wheat during both crop periods *i.e.*, 2022-2023 and 2023-2024 with pooled data.

| | | 2022-23 | | 2023-24 | | POOLED | |
|---|---|---|---|---|---|---|---|
| | | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) |
| RDF (50%) | FYM (12.5 t ha$^{-1}$) | 57.390 | 58.120 | 58.490 | 59.200 | 57.940 | 58.660 |
| | FYM (14.5 t ha$^{-1}$) | 60.420 | 60.080 | 61.520 | 61.280 | 60.970 | 60.680 |
| | FYM (16.5 t ha$^{-1}$) | 61.420 | 60.750 | 62.520 | 61.940 | 61.970 | 61.350 |
| RDF (75%) | FYM (12.5 t ha$^{-1}$) | 58.410 | 57.730 | 59.510 | 58.920 | 58.960 | 58.330 |
| | FYM (14.5 t ha$^{-1}$) | 60.420 | 67.100 | 61.510 | 68.340 | 60.970 | 67.720 |
| | FYM (16.5 t ha$^{-1}$) | 67.060 | 67.080 | 67.850 | 68.270 | 67.460 | 67.680 |
| RDF (100%) | FYM (12.5 t ha$^{-1}$) | 64.750 | 65.080 | 65.850 | 66.230 | 65.300 | 65.660 |
| | FYM (14.5 t ha$^{-1}$) | 65.050 | 67.780 | 66.170 | 68.980 | 65.610 | 68.380 |
| | FYM (16.5 t ha$^{-1}$) | 65.400 | 69.790 | 66.820 | 71.000 | 66.110 | 70.400 |
| CD ($p$<0.05) | | 1.799 | | 1.623 | | 1.703 | |

**Table 4:** Effect of combined use of inorganic fertilizer, organic manure, and foliar application of seaweed- based bio-stimulant on straw yield (measured in quintal per hectare) of wheat during both crop periods *i.e.*, 2022-2023 and 2023-2024 with pooled data.

| | | 2022-23 | | 2023-24 | | POOLED | |
|---|---|---|---|---|---|---|---|
| | | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) |
| RDF (50%) | FYM (12.5 t ha$^{-1}$) | 92.380 | 93.100 | 93.820 | 94.000 | 93.100 | 93.550 |
| | FYM (14.5 t ha$^{-1}$) | 95.430 | 95.080 | 96.850 | 96.720 | 96.140 | 95.900 |
| | FYM (16.5 t ha$^{-1}$) | 96.420 | 95.750 | 97.850 | 97.380 | 97.140 | 96.570 |
| RDF (75%) | FYM (12.5 t ha$^{-1}$) | 93.570 | 92.720 | 94.840 | 94.360 | 94.210 | 93.540 |
| | FYM (14.5 t ha$^{-1}$) | 95.410 | 102.100 | 96.850 | 103.730 | 96.130 | 102.920 |
| | FYM (16.5 t ha$^{-1}$) | 101.740 | 102.330 | 103.180 | 103.720 | 102.460 | 103.030 |
| RDF (100%) | FYM (12.5 t ha$^{-1}$) | 99.740 | 100.080 | 101.180 | 101.720 | 100.460 | 100.900 |
| | FYM (14.5 t ha$^{-1}$) | 100.070 | 102.770 | 101.510 | 104.410 | 100.790 | 103.590 |
| | FYM (16.5 t ha$^{-1}$) | 100.710 | 104.780 | 101.820 | 106.420 | 101.270 | 105.600 |
| CD ($p$<0.05) | | 1.638 | | 1.718 | | 1.674 | |

**Table 5:** Effect of combined use of inorganic fertilizer, organic manure, and foliar application of seaweed- based bio-stimulant on biological yield (measured in quintal per hectare) of wheat during both crop periods *i.e.*, 2022-2023 and 2023-2024 with pooled data.

| | | 2022-23 | | 2023-24 | | POOLED | |
|---|---|---|---|---|---|---|---|
| | | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) |
| RDF (50%) | FYM (12.5 t ha$^{-1}$) | 149.770 | 151.220 | 152.31 | 153.2 | 151.04 | 152.21 |
| | FYM (14.5 t ha$^{-1}$) | 155.850 | 155.160 | 158.37 | 158 | 157.11 | 156.58 |
| | FYM (16.5 t ha$^{-1}$) | 157.840 | 156.500 | 160.37 | 159.32 | 159.11 | 157.91 |
| RDF (75%) | FYM (12.5 t ha$^{-1}$) | 151.980 | 150.450 | 154.35 | 153.28 | 153.17 | 151.87 |
| | FYM (14.5 t ha$^{-1}$) | 155.830 | 169.200 | 158.36 | 172.07 | 157.1 | 170.64 |
| | FYM (16.5 t ha$^{-1}$) | 168.800 | 169.410 | 171.03 | 171.99 | 169.92 | 170.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| RDF (100%) | FYM (12.5 t ha$^{-1}$) | 164.490 | 165.160 | 167.03 | 167.95 | 165.76 | 166.56 |
| | FYM (14.5 t ha$^{-1}$) | 165.120 | 170.550 | 167.68 | 173.39 | 166.4 | 171.97 |
| | FYM (16.5 t ha$^{-1}$) | 166.110 | 174.570 | 168.64 | 177.42 | 167.38 | 176 |
| CD ($p$<0.05) | | 3.412 | | 3.337 | | 3.365 | |

**Table 6:** Effect of combined use of inorganic fertilizer, organic manure, and foliar application of seaweed- based bio-stimulant on harvest index (measured in percentage) of wheat during both crop periods *i.e.*, 2022-2023 and 2023-2024 with pooled data.

| | | 2022-23 | | 2023-24 | | POOLED | |
|---|---|---|---|---|---|---|---|
| | | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) | SWBS (625 ml ha$^{-1}$) | SWBS (1250 ml ha$^{-1}$) |
| RDF (50%) | FYM (12.5 t ha$^{-1}$) | 38.320 | 38.430 | 38.4 | 38.64 | 38.36 | 38.54 |
| | FYM (14.5 t ha$^{-1}$) | 38.770 | 38.720 | 38.85 | 38.78 | 38.81 | 38.75 |
| | FYM (16.5 t ha$^{-1}$) | 38.910 | 38.820 | 38.98 | 38.88 | 38.95 | 38.85 |
| RDF (75%) | FYM (12.5 t ha$^{-1}$) | 38.430 | 38.370 | 38.56 | 38.44 | 38.49 | 38.41 |
| | FYM (14.5 t ha$^{-1}$) | 38.770 | 39.660 | 38.84 | 39.72 | 38.81 | 39.69 |
| | FYM (16.5 t ha$^{-1}$) | 39.730 | 39.600 | 39.67 | 39.69 | 39.7 | 39.65 |
| RDF (100%) | FYM (12.5 t ha$^{-1}$) | 39.360 | 39.400 | 39.42 | 39.43 | 39.39 | 39.42 |
| | FYM (14.5 t ha$^{-1}$) | 39.400 | 39.740 | 39.46 | 39.78 | 39.43 | 39.76 |
| | FYM (16.5 t ha$^{-1}$) | 39.370 | 39.980 | 39.62 | 40.02 | 39.5 | 40 |
| CD ($p$<0.05) | | 0.292 | | 0.19 | | 0.228 | |

## Conclusion

The investigation into the synergistic impact of inorganic and organic fertilizers, coupled with a bio-stimulant derived from *Kappaphycus alvarezii*, on various yield attributes of wheat has yielded significant insights. Grain yield, a fundamental measure of wheat productivity, exhibited notable interactions among all three factors studied. Particularly, the treatment combination of RDF @100% + FYM @16.5 t ha$^{-1}$ + SWBS @1250 ml ha$^{-1}$ demonstrated the highest grain yield, emphasizing the efficacy of this integrated approach. Straw yield, an essential byproduct of wheat cultivation, also showcased substantial responses to different treatment combinations. Notably, the treatment $T_{18}$ consistently yielded the highest straw production, underscoring its effectiveness in maximizing overall output. Biological yield, encompassing total biomass production, revealed significant interactions among the studied factors. Treatment $T_{18}$ emerged as the top performer, highlighting its ability to promote robust plant growth and biomass accumulation. Harvest index, a key indicator of resource allocation efficiency, exhibited significant responses to the treatment combinations. Notably, $T_{18}$ demonstrated the highest harvest index values across both research years, indicating superior resource utilization and grain formation efficiency. Overall, the findings underscore the importance of integrated nutrient management strategies involving inorganic and organic fertilizers, alongside bio-stimulants, in optimizing wheat yield attributes. The identified treatment combinations hold promise for enhancing wheat productivity sustainably, thereby contributing to food security and agricultural sustainability. Further research and field trials are warranted to validate these findings and elucidate the underlying mechanisms driving the observed synergies.

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